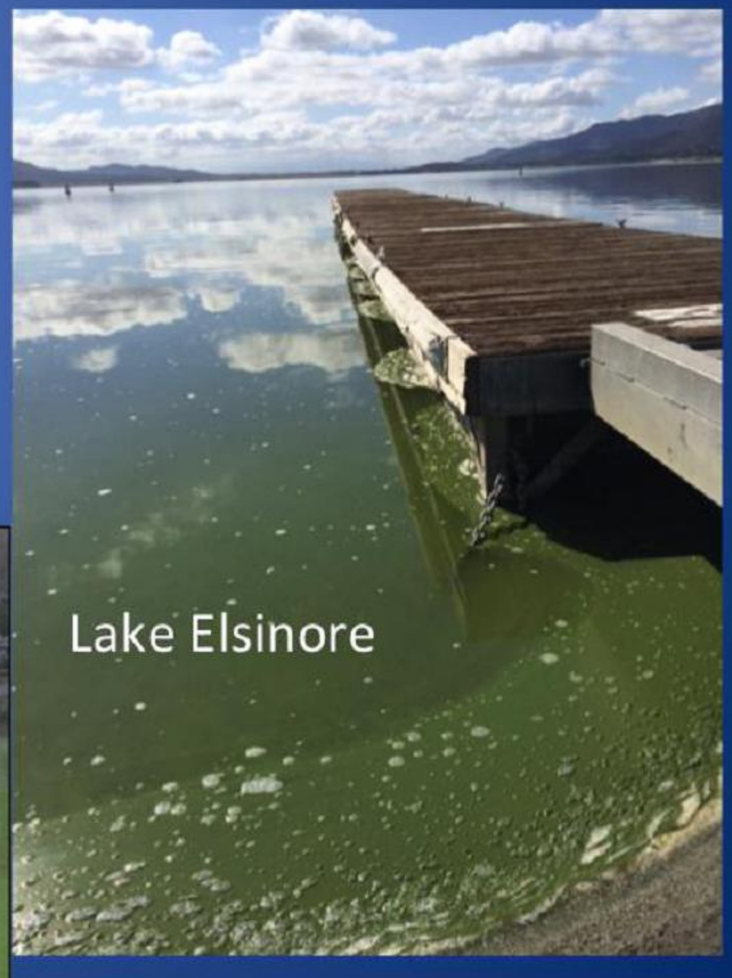
Widespread Prevalence of Harmful Algae and Cyanobacteria from a Variety of California Waterbodies

David Caron and Avery Tatters, University of Southern California
Meredith Howard, Southern California Coastal Water Research Project



Overview of Webinar

- Some Introduction, Background and Context
- What types of harmful algal/protozoan/cyanobacteria do we face in freshwater, and in CA in particular?
  - Toxic & nuisance algae (unappreciated threats in CA freshwater)
  - Pathogenic protists (rare but significant)
  - Toxic cyanobacteria (a real and present danger in CA)

- Cyanobacterial diversity and taxonomy

- What are the CA specific cyanobacteria and toxin issues?
  - Where are recurring blooms?
  - Screening assessments and field surveys

- What is CA doing to mitigate freshwater HABs?

Why toxin production?

- **Allelopathy** (kill your competitors!)
  -major nutrient acquisition
  (N, P, Si)

- **Grazer Deterrence** (tasting bad is good)

- **Metals** (too many, or not enough)
  (Fe, Cu)

Context: Algal toxins encountered in coastal California ecosystems

Microalgae	Toxin(s)	Poisoning Event
Diatoms *Pseudo-nitzschia* spp. *P. australis*[b] *P. cuspidata*[b] *P. delicatissima*[b] *P. fraudulenta*[b] *P. multiseries*[b] *P. pungens*[b] *P. pseudodelicatissima*[b] *P. seriata*[a]	Domoic acid (DA)	Amnesic Shellfish Poisoning (ASP) Human effects • Gastro-intestinal symptoms • Neurologic symptoms • Death Ecosystem effects • Marine mammal mortalities • Bird mortalities
Dinoflagellates *Alexandrium* spp. *A. acatenella*[a] *A. catenella*[b] *A. fundyense*[a] *A. hiranoi*[a] *A. ostenfeldii*[a] *A. tamarense*[a]	Saxitoxins (STXs)	Paralytic Shellfish Poisoning (PSP) Human effects • Gastro-intestinal symptoms • Paralysis • Death Ecosystem effects • Marine mammal mortalities
Dinoflagellates *Dinophysis* spp.	Okadaic acid (OA) Dinophysistoxins (DTXs)	Diarrhetic Shellfish Poisoning (DSP)

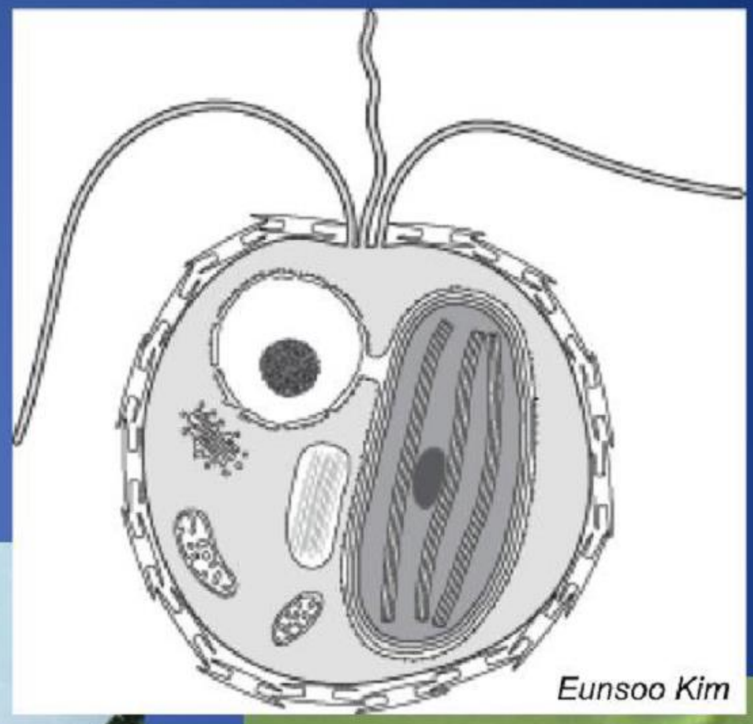
California estuaries as locations of multiple ecosystems stressors

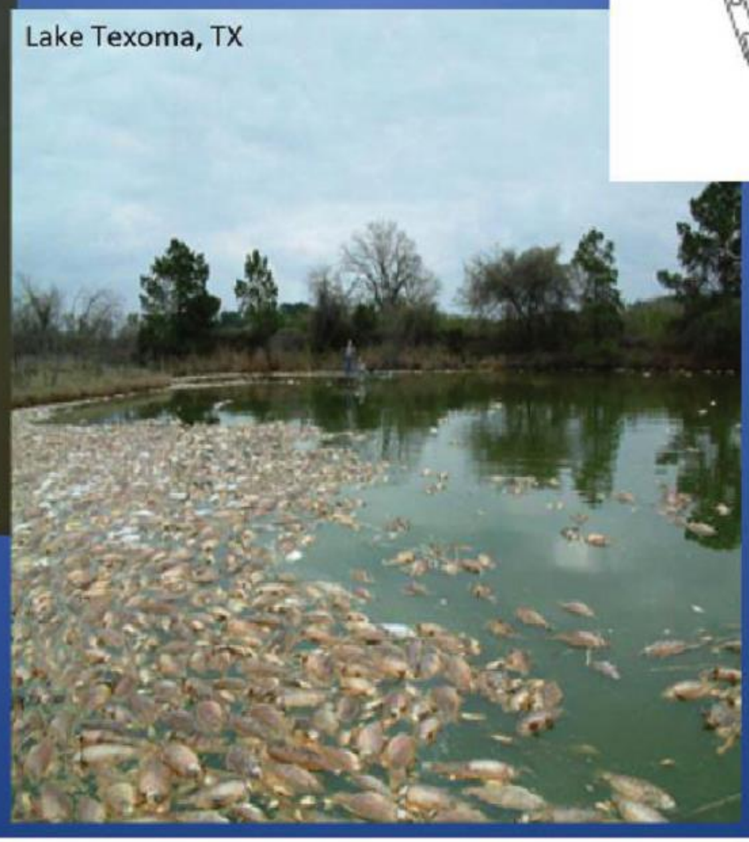
Toxin/class	Mode of action in	Estuary (1-33ppt)		Marine (> 33ppt)	
Domoic Acid	KA/GLU receptor binding antagonist	?	*Pseudo-nitzschia* spp.	ubiquitous	*Pseudo-nitzschia* spp.
Paralytic Shellfish Poisoning Toxins (PSPs)	Na^+ channel antagonist, neurotoxins	San Elijo Lagoon, Batiquitos Lagoon	*Alexandrium* sp.*, *Aphanizomenon* sp., *Cylindrospermopsis* sp.*, *Lyngbya* sp.*, *Phormidium* sp.*	Newport Point, Ventura Harbor, Jalama	*Alexandrium* spp.*, *Lyngbya* sp.,
Diarrhetic Shellfish Poisoning Toxins (DSPs)	Protein Phosphatase inhibitor (PPi)	?	*Dinophysis* spp.	?	*Dinophysis* spp.
Microcystins	hepatotoxins, PPi	San Elijo Lagoon	*Microcystis* spp.*	?	-
Anatoxins	nAChR agonists	Lagoon at Pt. Mugu, Santa Clara River estuary	*Anabaena* spp., *Dolichospermum* sp., *Oscillatoria* spp.?	?	*Oscillatoria* spp.
Cylindrospermopsins	Potent hepatotoxins, multiple effects	upstream from lagoon at Pt. Mugu, Santa Clara River	*Cylindrospermopsis raciborskii*	?	-
Nodularin	potent PPi	Santa Clara River	*Nodularia* sp. *	?	-
Cycloimines	nAChR and mAChR antagonists, neurotoxins	?	?	Newport Point, Point Dume, Ventura Harbor	*Gymnodinium* sp., *Alexandrium* spp. *
Lyngbyatoxin A	Dermatitis, tumor promoters, other	Ventura County, Los Penasquitos Lagoon	*Lyngbya* spp.*	Ventura County	*Lyngbya* spp.*
Phormidolide	unknown	Santa Clara River estuary, Jalama creek	*Phormidium* spp.*	?	*Phormidium* spp.
Microginins	metalloprotease inhibitor	San Elijo Lagoon	*Microcystis* sp.	?	?
Microviridins	PPi, elastase inhibitor	San Elijo Lagoon	*Microcystis* sp.	?	?
Karlotoxins	cytotoxins	?	*Karlodinium veneficum*	?	*Karlodinium veneficum*

Before we get to cyanobacteria…
…a few freshwater algal species to keep in mind.

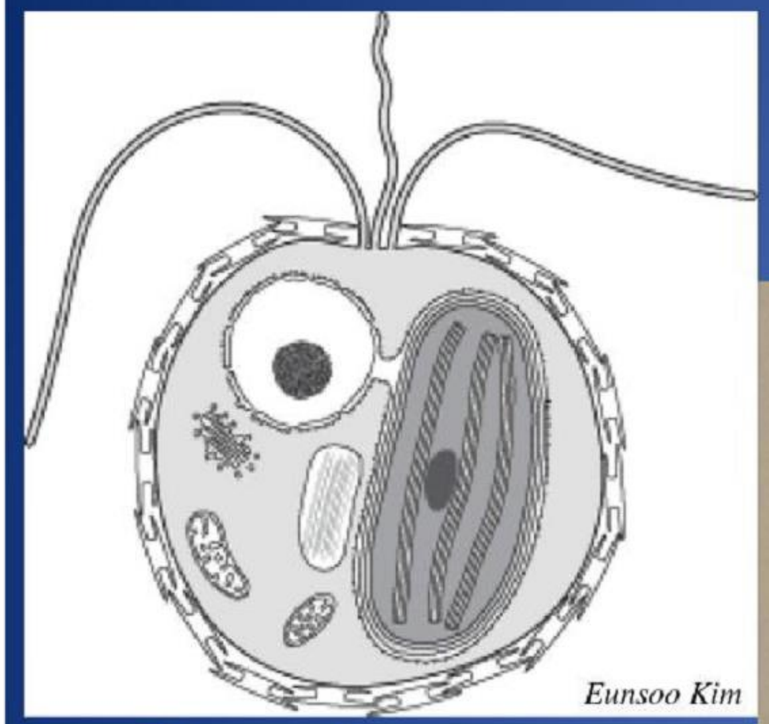
Prymnesium parvum
(the 'golden alga')


Lake Texoma, TX


Eunsoo Kim


Lake Texoma, TX

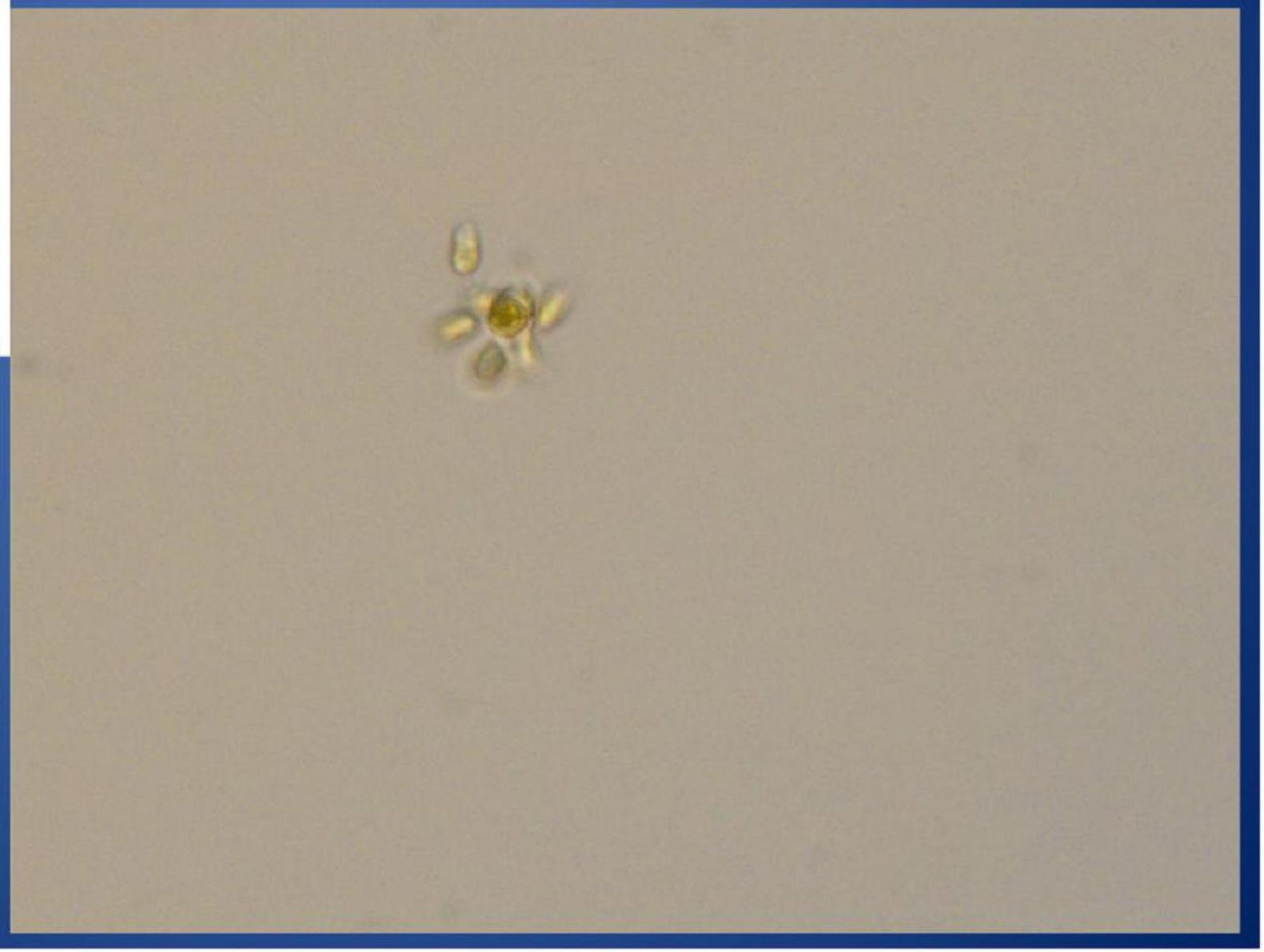
Prymnesium can grow easily as an alga, but is also an excellent predator



Prymnesium parvum

Multiple Toxins & Effects
- Fish (gill damage)
- Zooplankton
- Cell membranes of co-occurring algae and protozoa

EDAB: Ecosystem Disruptive Algal Blooms



A very toxic alga moving through the southwest U.S.

NEWS > LOCAL

Hundreds of Dead Fish Surface in A Lake

The fish apparently died of oxygen deprivation due to an algae bloom in the water

Golden alga causing thousands of fish deaths in Arizona river

BY: abc15.com staff , Mike Pelton
POSTED: 2:35 PM, Jul 6, 2012
UPDATED: 6:37 PM, Jul 6, 2012
TAG: csa other | region csa

TOXIC ALGAE CAUSE OF 100 ELK DEATHS IN NORTHEASTERN NM

New Mexico Department of Game & Fish sent this bulletin at 10/22/2013 10:37 AM MDT

New Mexico
WILDLIFE NEWS
www.wildlife.state.nm.us
James S. Lane Jr., Director

New Mexico Department of Game and Fish
Media contact: Rachel Shockley, (505) 476-8071
Public contact: (888) 248-6866
rachel.shockley@state.nm.us

FOR IMMEDIATE RELEASE, OCT. 22, 2013:
TOXIC ALGAE CAUSE OF 100 ELK DEATHS IN NORTHEASTERN NM

SANTA FE – The Department of Game and Fish has concluded that a toxic algae bloom caused the deaths of more than 100 elk discovered Aug. 27 in northeastern New Mexico.

Golden alga cause of fish kill on Altus-Lugert Lake

by Ed Godfrey *Published: January 4, 2013*

Altus-Lugert Lake is the latest body of water in southwest Oklahoma where fish are dying as a result of golden alga blooms.
The fish kill started the week before Christmas and became worse last week with several thousand fish dying in the lake, said Larry Cofer, southwest fisheries chief of the Oklahoma Department of Wildlife Conservation.

A very toxic alga moving through the southwest U.S.

inMaricopa.com

94° - Clear
Low: 72° High: 108

HOME NEWS BUSINESS COMMUNITY EDUCATION GOVERNMENT PUBLIC SAFETY

Golden algae suspected in fish kill

Submitted by city of Maricopa
May 21, 2012 - 11:11 am

Tweet Like 0 SHARE

This past weekend, approximately 250 dead fish were discovered floating on the surface of Pacana Park lake.

NEWS > LOCAL

Hundreds of Dead Fish Surface in Agoura Hills Lake

The fish apparently died of oxygen deprivation due to an algae bloom in the water.

By Olga Spilewski and Gordon Tokumatsu

…and becoming more common in CA.

AquaTechnex

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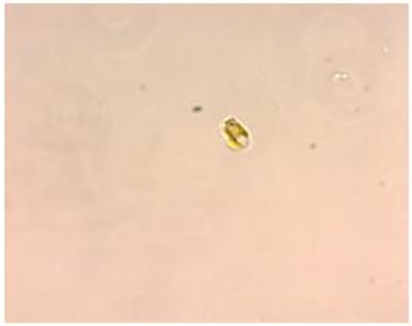
FISH KILLING GOLDEN ALGAE DISCOVERED IN CALIFORNIA



Golden Algae, doesn't look like much, but produces fish toxicant that is deadly

Aquatechnex biologists are diagnosing the first cases of *Prymnesium parveum* or Golden Algae at a couple of our projects in Southern California. This species is a tiny one celled organism with two small "tails" that can be used to move through the water column. It was discovered in Arizona in 2005 and we have not seen it until the present in California projects. Golden Algae release toxins that affect gill breathing aquatic organisms such

Local

Testing Underway After Thousands Of Fish Die-Off In Menifee Lake

May 2, 2014 1:58 PM

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Didymosphenia germinata
('Didymo': rock snot)

Mark Hoddle: UC Riverside


• Highly Invasive
• Resistant to degradation
• Adverse effects on fish and invertebrate populations

Naegleria fowleri

(Amoebic Meningoencephalitis)

Images from: http://www.cdc.gov/parasites/naegleria/

Los Angeles Times MEMBER CENTER L.A. NOW CALIFORNIA ENTERTAINMENT ARTS & CULTURE SPORTS BUSINESS NATION MORE

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Water parasite kills 9-year-old

August 06, 2008 | David Kelly | Times Staff Writer

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Riverside County health officials are urging swimmers to use caution after the death Saturday of a Lake Elsinore child infected with a waterborne parasite.

Authorities said it was unknown exactly where the 9-year-old boy contracted the deadly Naegleria fowleri amoeba. He had gone swimming in Lake Elsinore several times this summer.

The parasite lives in warm freshwater lakes, rivers and poorly maintained swimming pools, experts say. It enters the brain through the nose, where it can cause a severe and nearly always fatal infection. This is the county's first confirmed case of the illness.

Sierra Wave Media

Inside. Outside. We cover the Eastside.

SEPTEMBER 3 - 6, 2015

LABOR DAY WEEKEND

Tragic local death caused by amoeba

by News Staff on July 3, 2015 in General, Public Event

- Press release from Inyo County Health Officer Dr. Richard Johnson

Family and friends are mourning the tragic death of a 21 year old Bishop resident who died recently from an extremely rare infection known as primary amebic meningoencephalitis (PAM). On June 16th, the woman – Jasmine Dee Reed – woke up from a nap with headache, nausea, and vomiting.

Search...

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Sierra 92.5-

"This is a heat-loving amoeba. As water temperatures go up, it does better," Beach said. "In future decades, as temperatures rise, we'd expect to see more cases."

Overview of Webinar

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- What types of harmful algal/protozoan/cyanobacteria do we face in freshwater, and in CA in particular?
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- Cyanobacterial diversity and taxonomy

- What are the CA specific Cyanobacteria and toxin issues?
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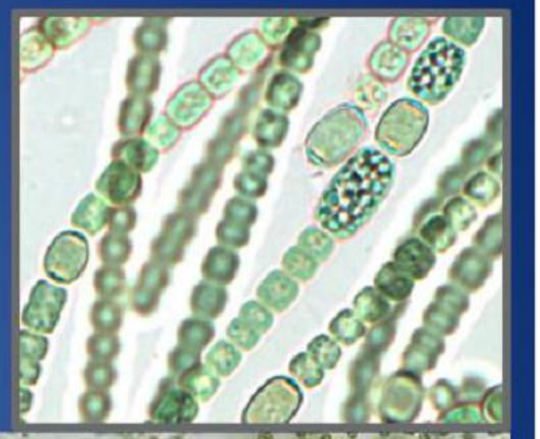
What Are Cyanobacteria and Cyanotoxins?

- >3 billion years old
- Occur in most waterbodies (fresh, brackish, marine)
- Similarities to algae:
  - Photosynthesize
  - Exist as single cells or as colonies
- Can form dense blooms
  - Potentially harmful (harmful algal bloom HAB)

- Cyanotoxins
  - >90 described
  - Common toxins include microcystins, anatoxin-a, cylindrospermopsin, saxitoxin
  - Bioaccumulate



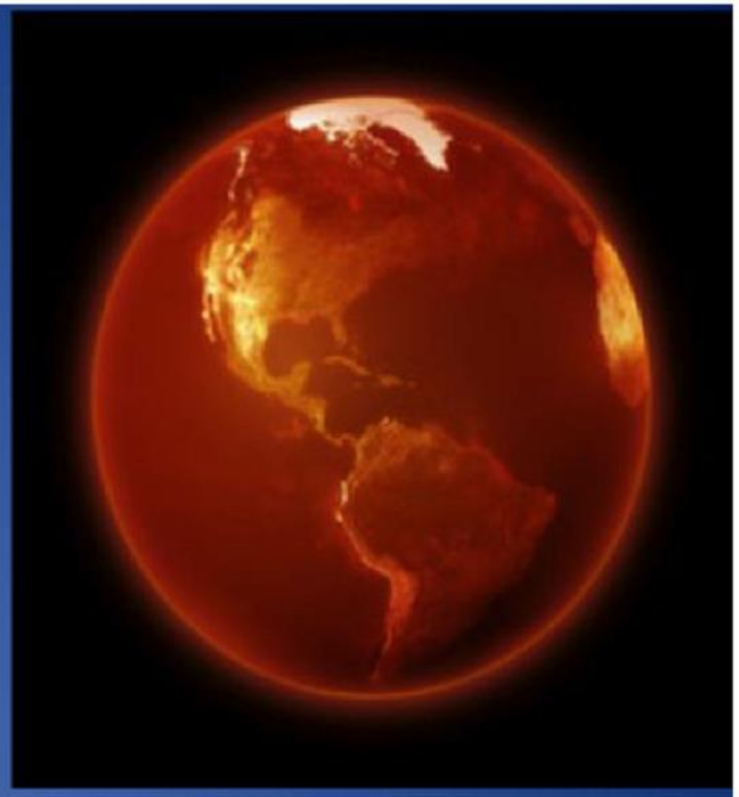
Why Care About Cyanotoxins?

- Health impacts and mortality to humans, domestic pets and wildlife
- Increasing problem globally
  - expanding distribution, increased frequency
- Environmental factors:
  - Climate change and warm temperatures
  - Increased nutrient inputs
  - Hydrologic modification (water residence time)

& SLOW!

Paerl et al. 2009, Paerl and Otten, 2013

Expectations with Climate Change



- Greenhouse warming is projected to increase sea surface temperatures in many locations by up to 4 to 5 °C by the year 2100
- Temperature is a fundamental driver of biochemistry
- Factors that accompany warming, e.g. stratification
- Temperature increases also implicated in biogeographical range shifts and increased length of 'bloom seasons or windows'
    - "Cyanobacteria like it hot"

California estuaries as locations of multiple ecosystems stressors

Toxin/class detected	Mode of action in mammals	Estuary (1-33ppt) Locality detected	likely producer	Marine (> 33ppt) Locality detected	likely producer
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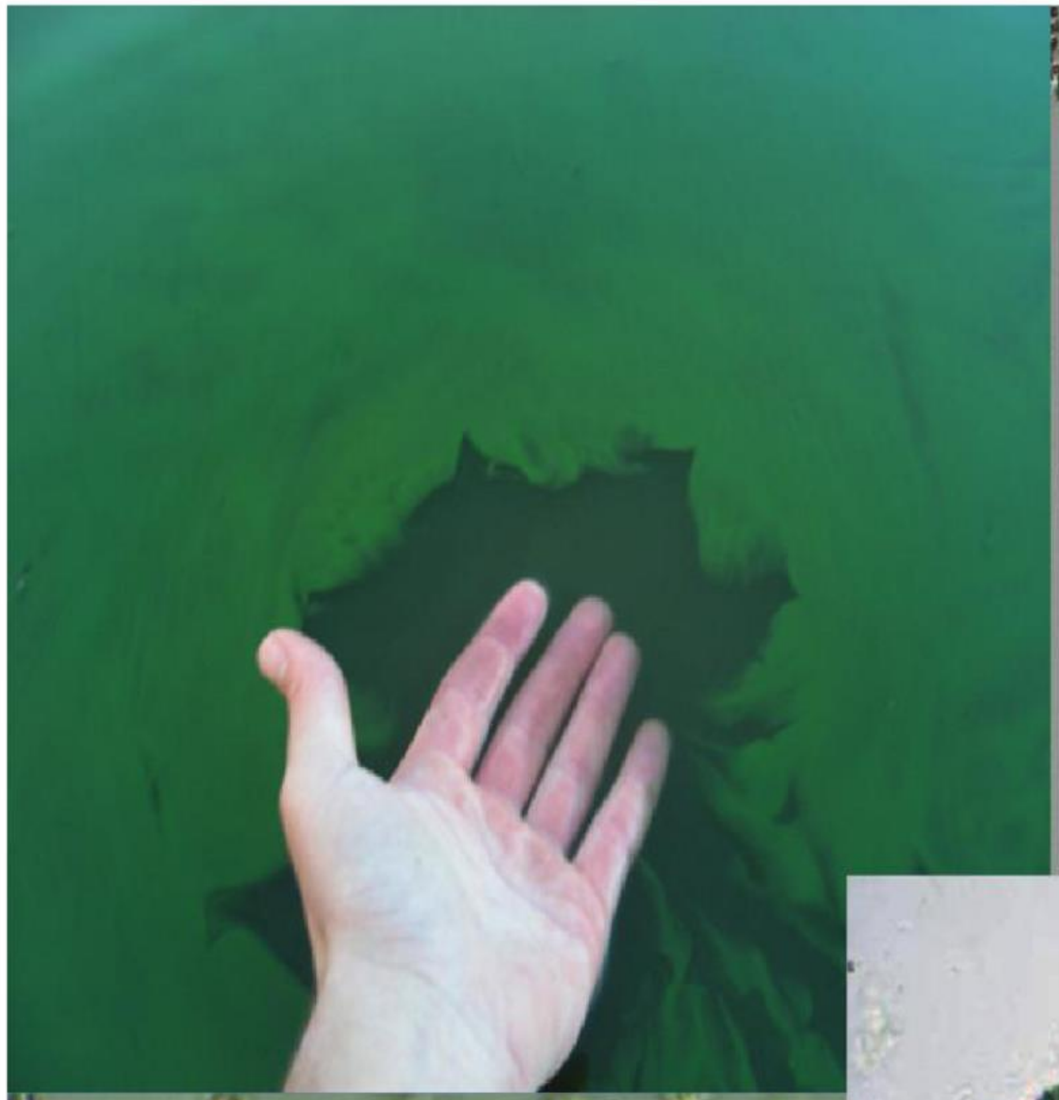
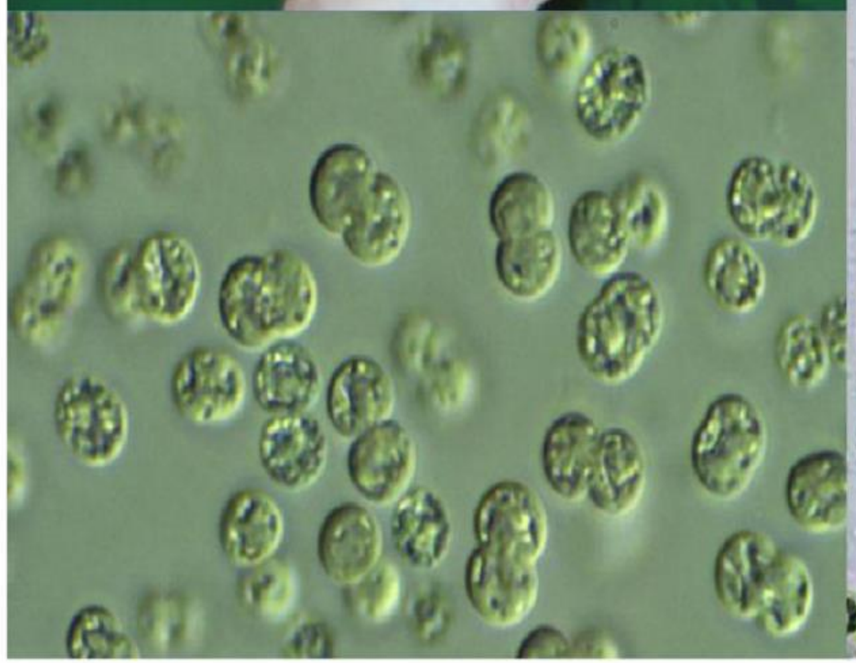
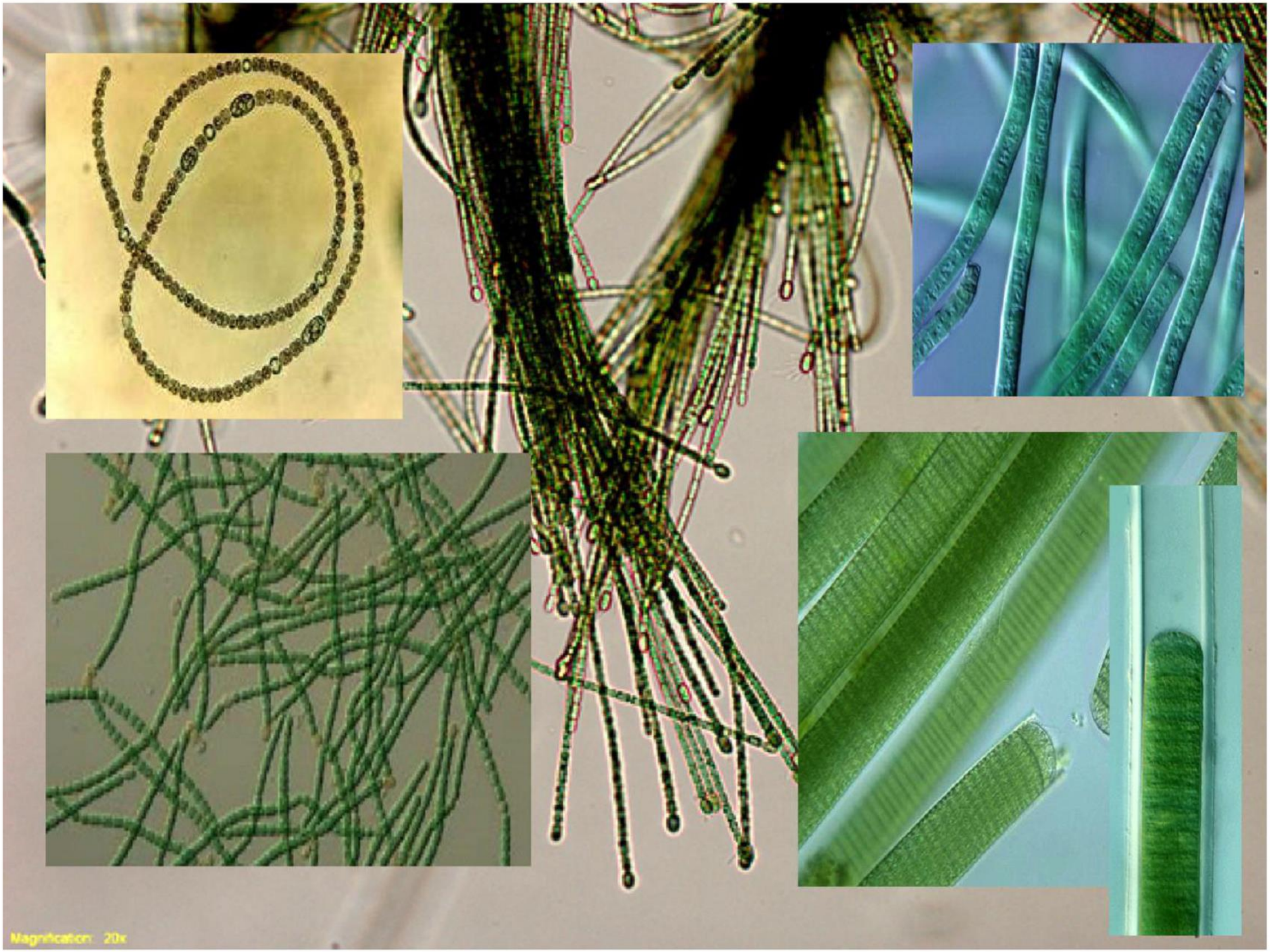




Northern & Central California Ecosystems

Algae bloom behind Klamath dam | James Norman

(Pinto Lake: Kudela lab, UCSC)

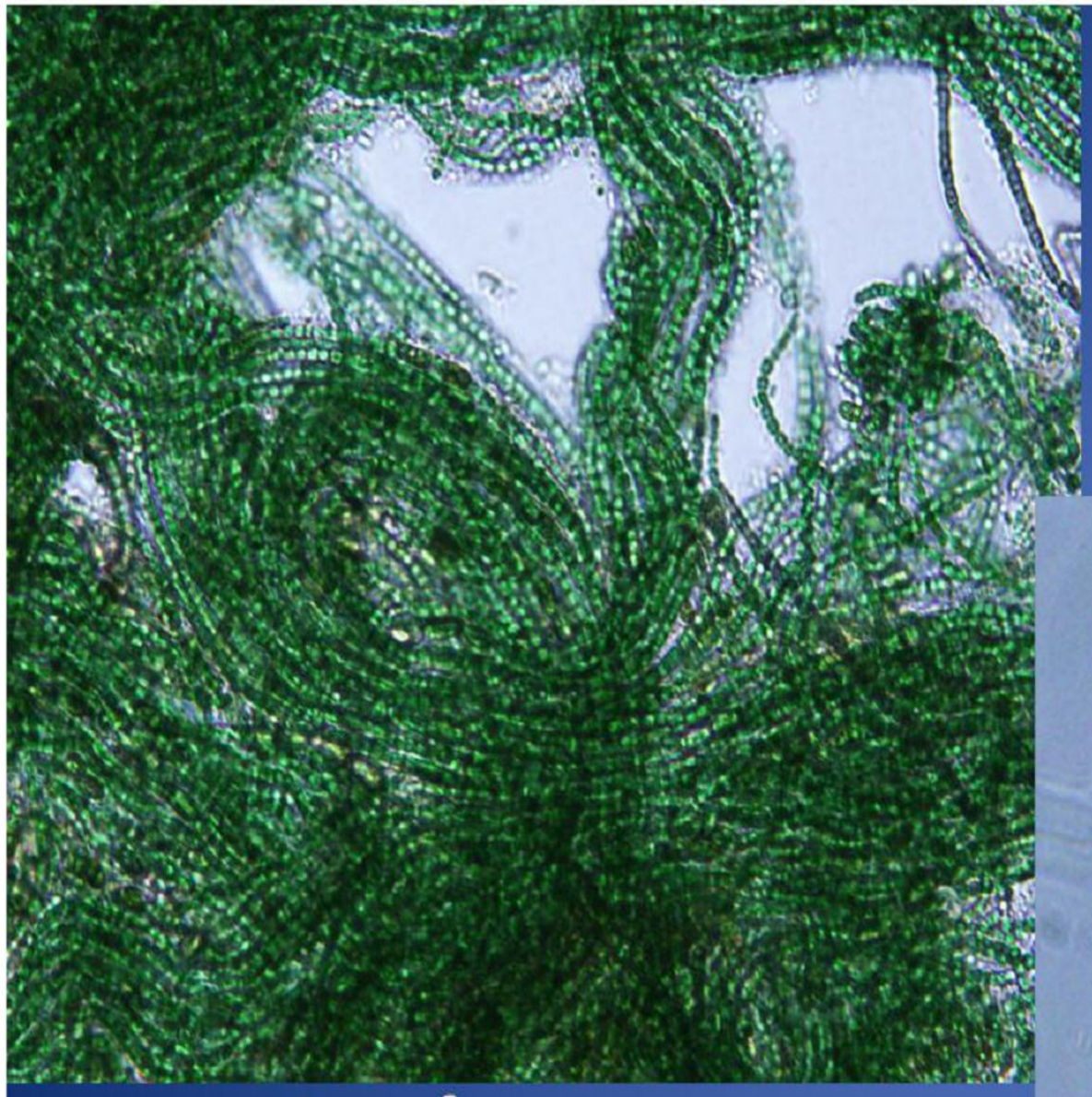

Magnification: 20x

Cyanobacterial Classification: A Hybrid Approach

- Taxonomy
  - conventional by design, but necessary for orientation in natural diversity
  - desired categorical unit = species
- Problematic with cyanobacteria
  - difficulty to ID at species level
  - cryptic diversity
- Traditional strategy based solely on morphology
  - what can be seen with a microscope.
  - variable characters = confounding
  - cell size, filament width, colony morphology, fixatives

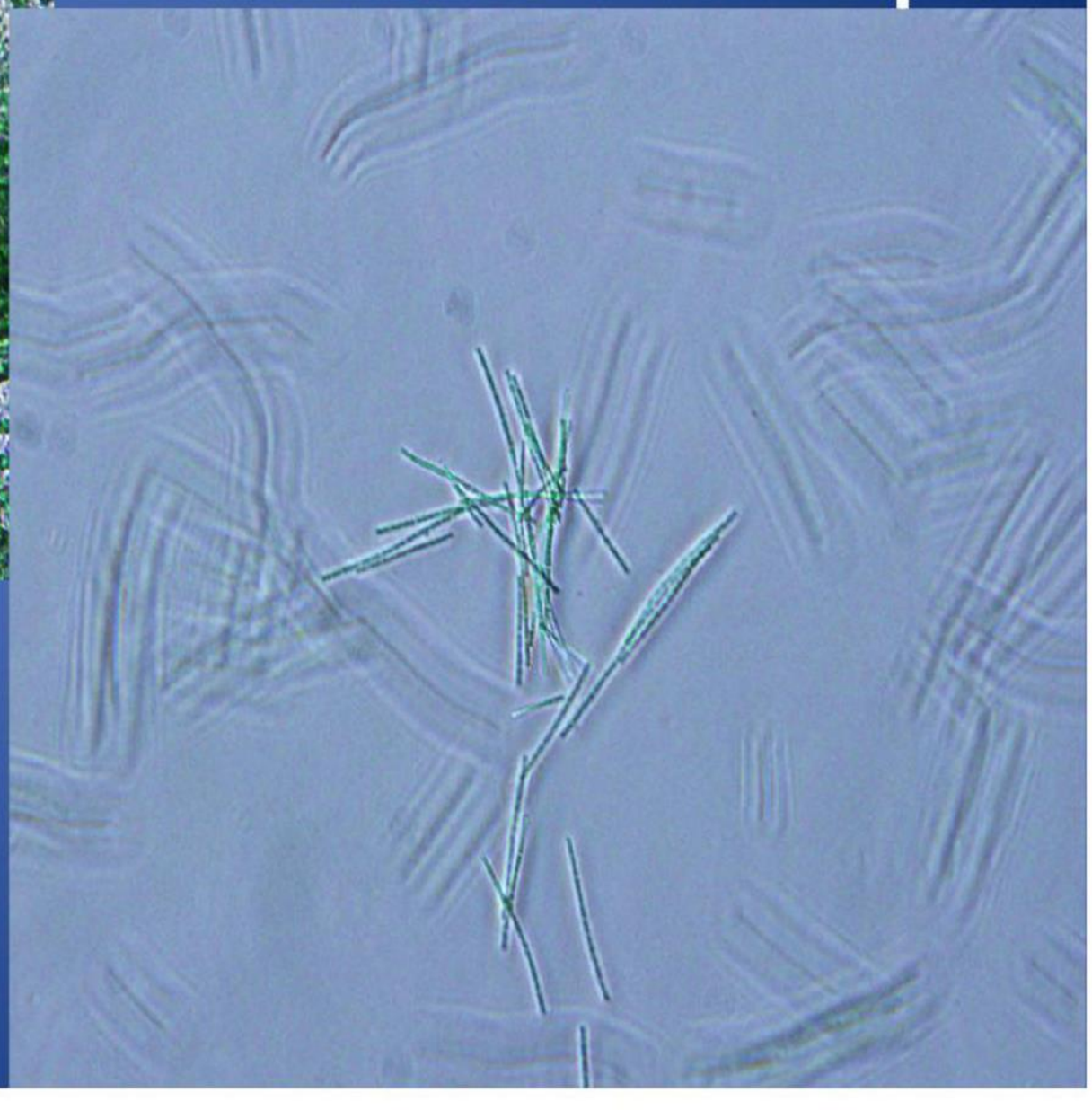
Cyanobacterial Classification: A Hybrid Approach

- Molecular methods:
  - DNA barcoding (categorizing using a short taxonomic marker)
  - differentiate toxic vs. non-toxic populations of some organisms
  - accuracy in identification
  - lag to monitoring application
  - lack of supporting reference database
- Weaving molecular and traditional methodology (perhaps even physiological traits) is necessary moving forward to properly delineate species.

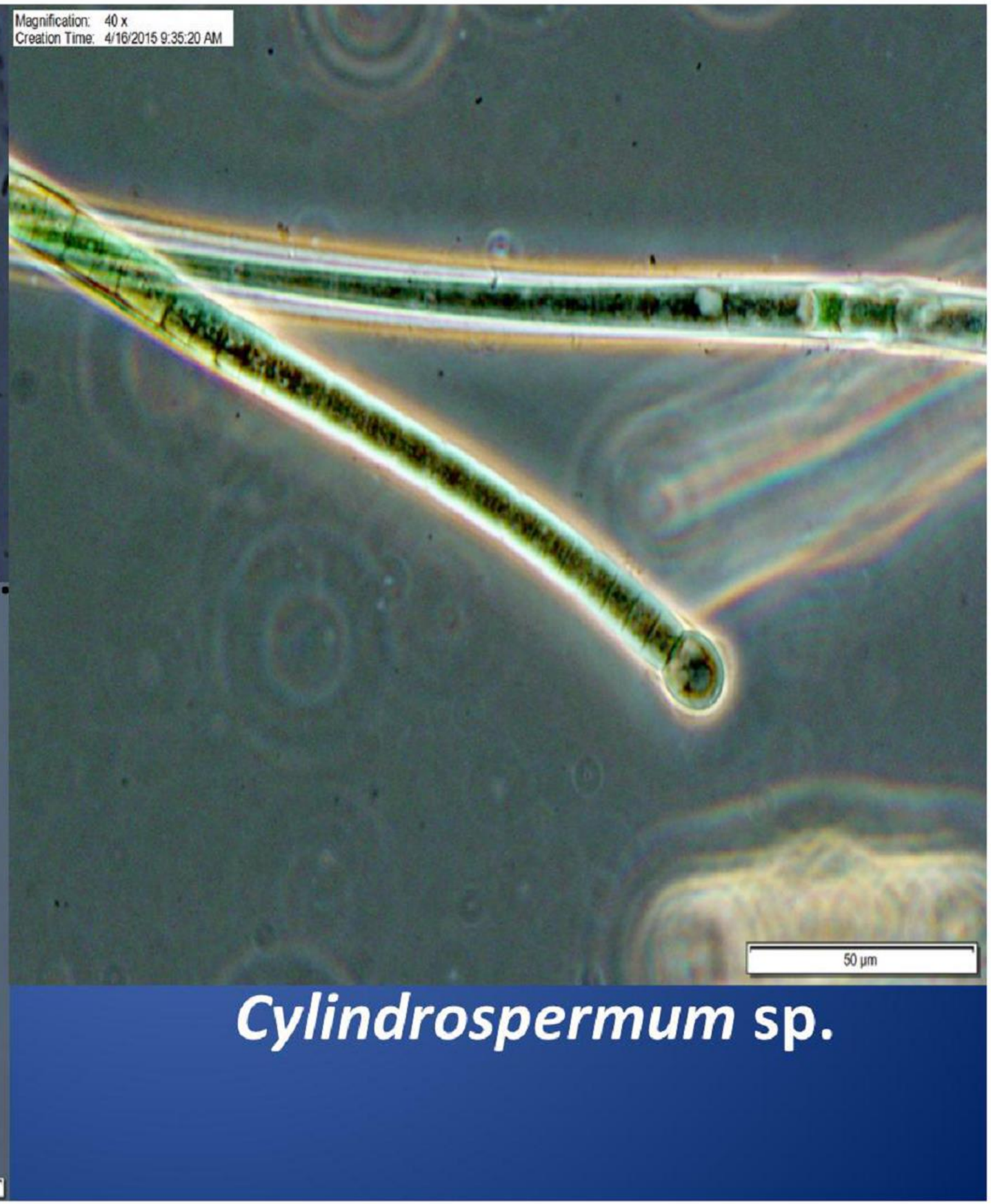


Anabaena sp.

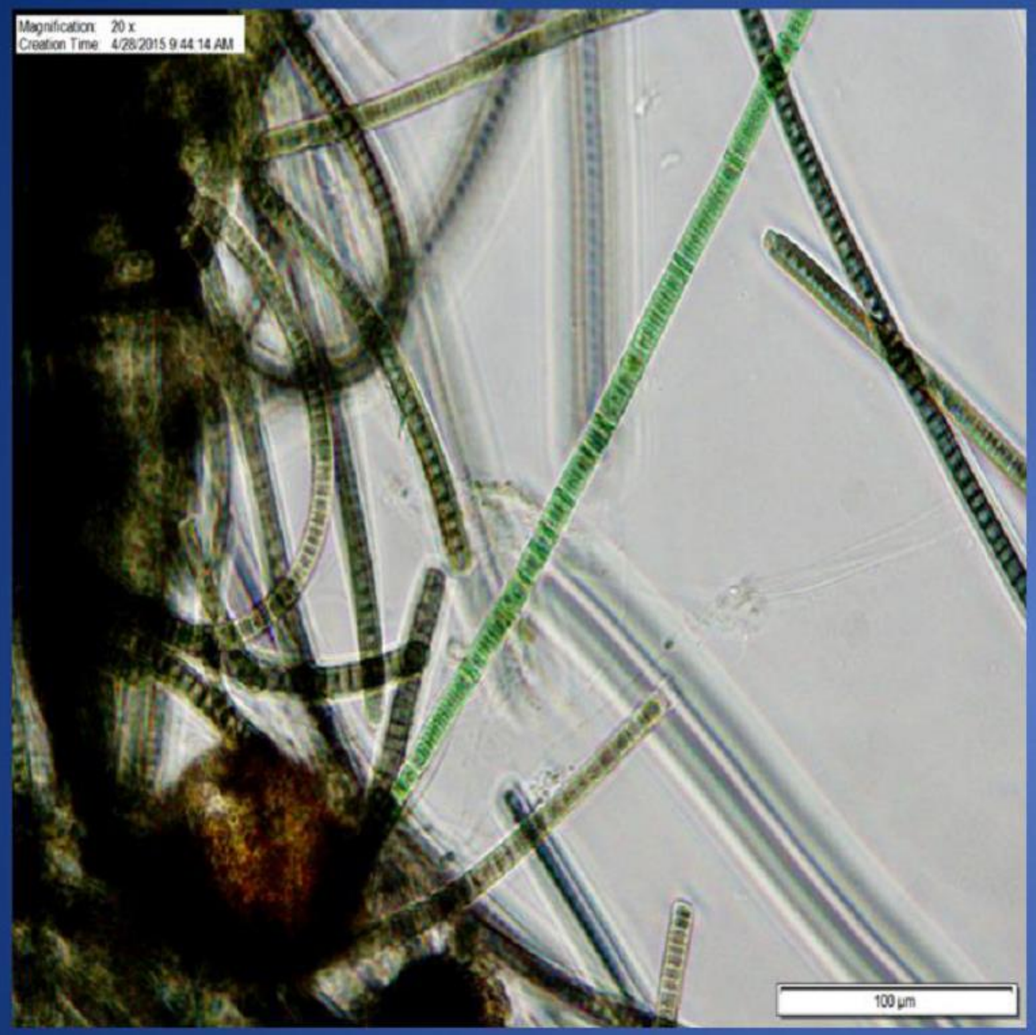
Pseudanabaena sp.

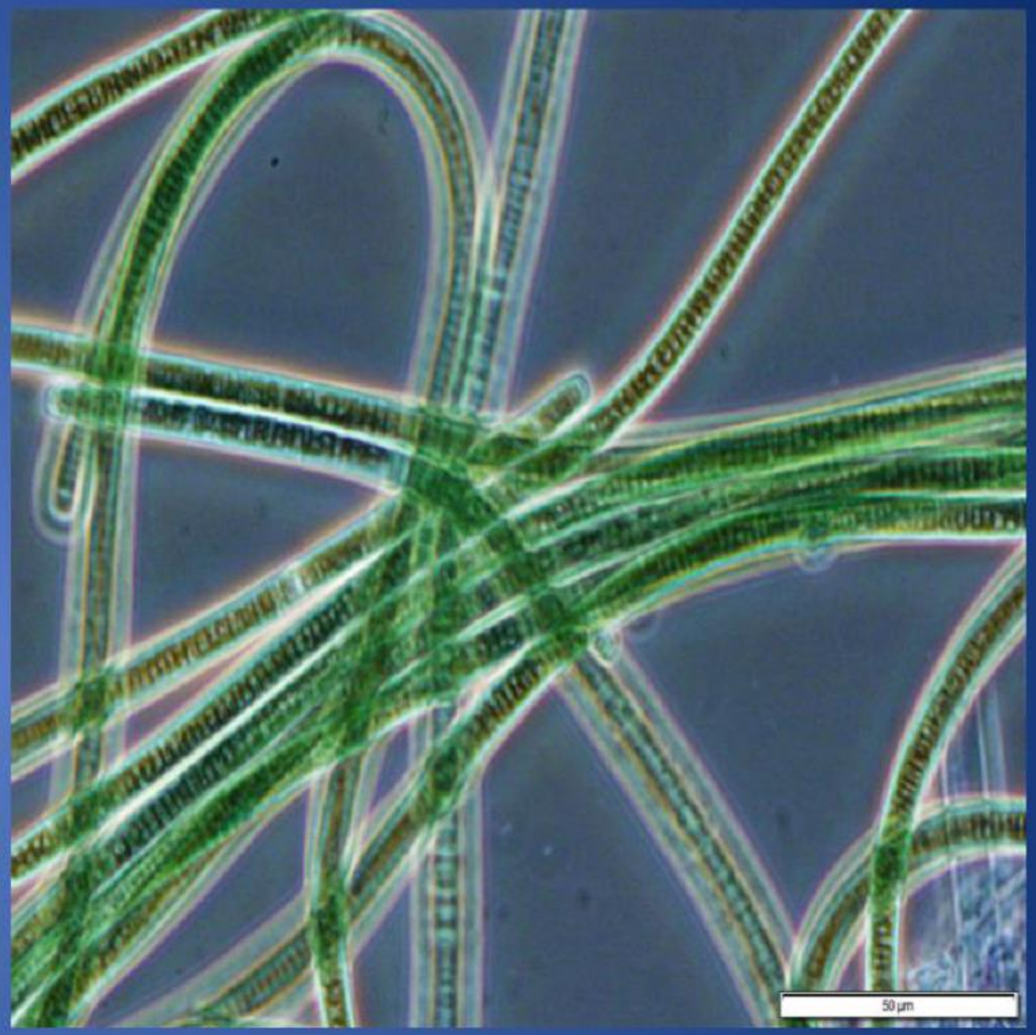


Cylindrospermopsis spp.



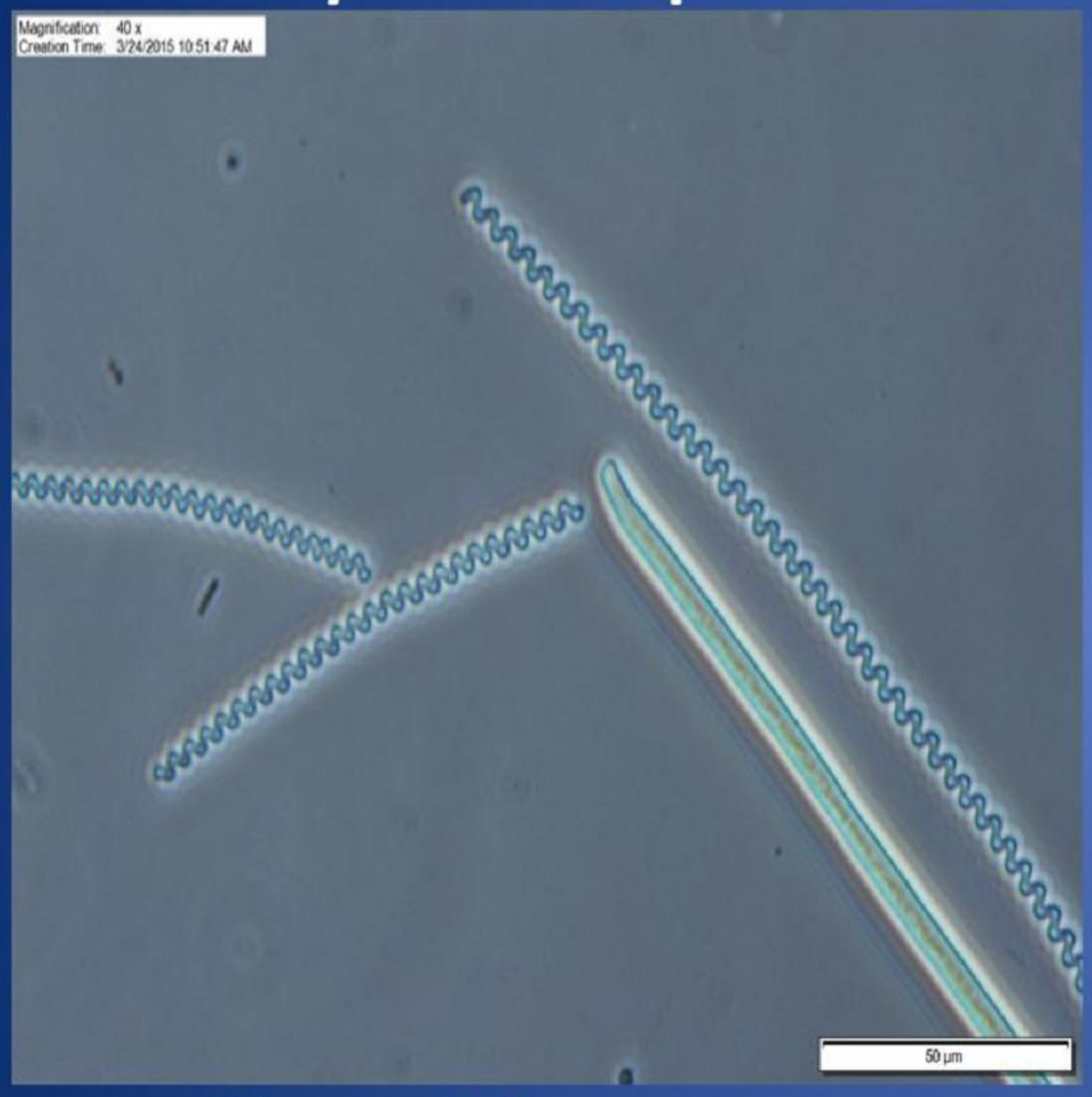
Cylindrospermum sp.





***Oscillatoria* spp.**

Spirulina sp.



Phormidium sp.

Unknown branched filament

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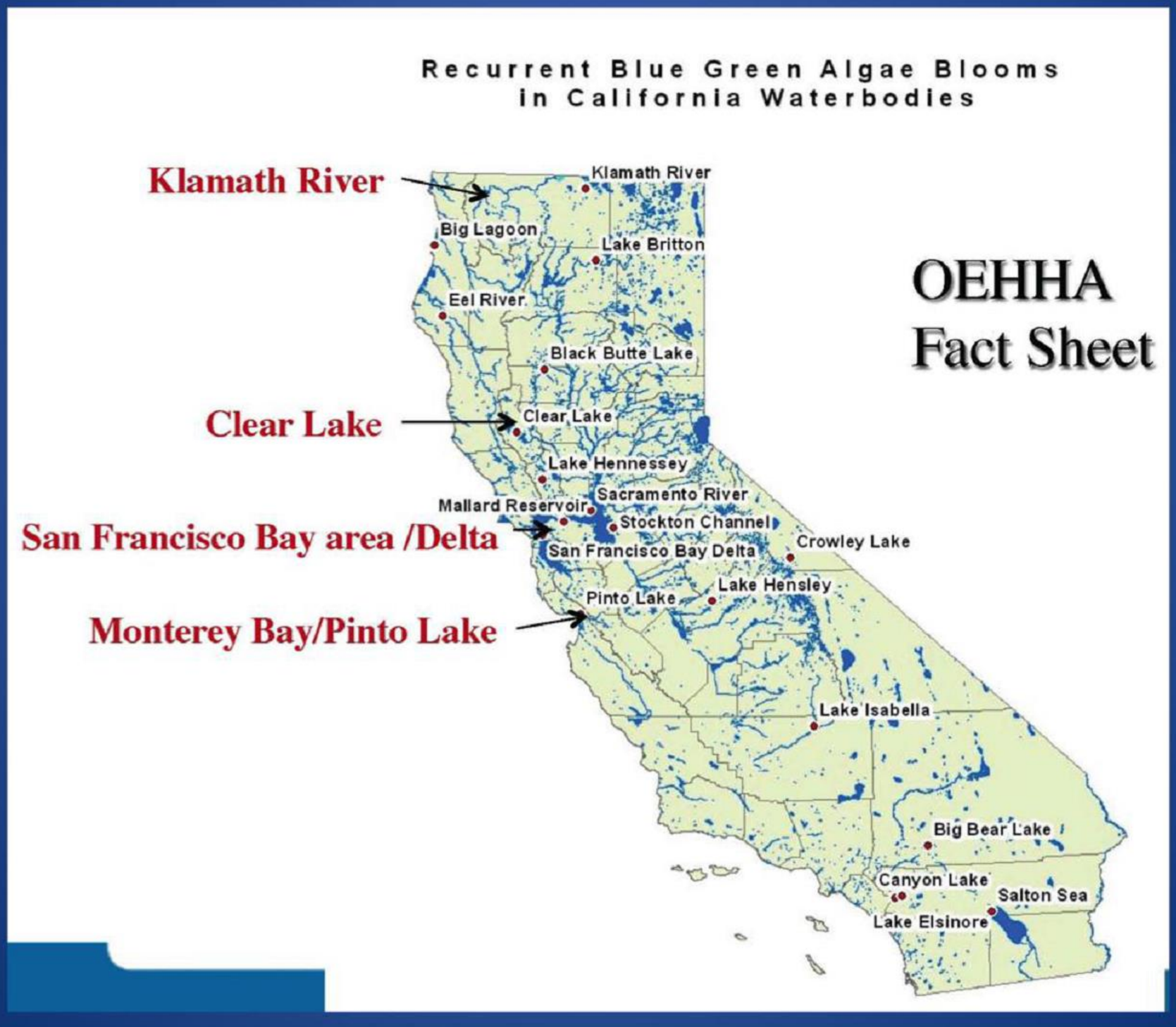
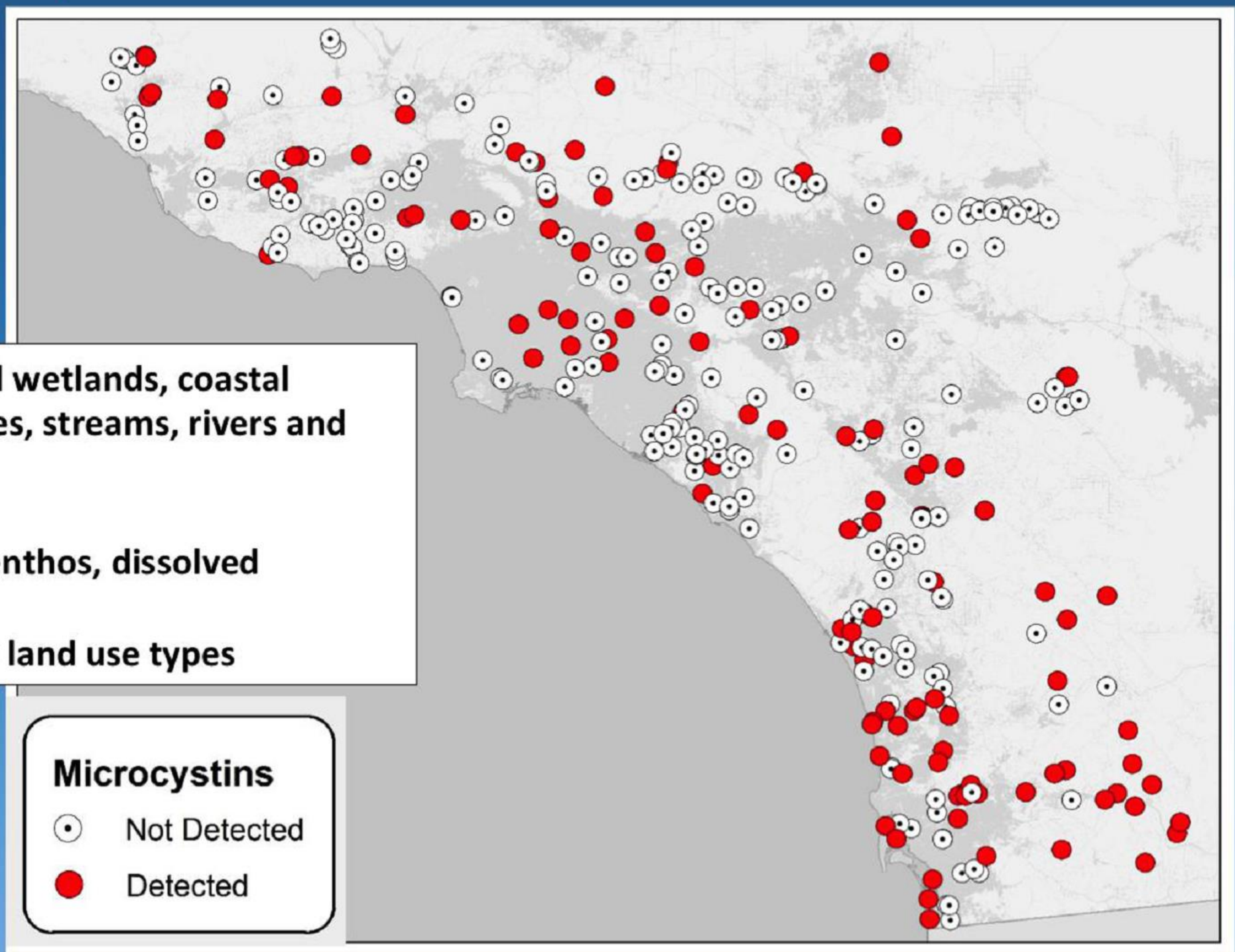
Well Documented Problem Areas in CA



Microcystins:
Widespread in Southern California Waterbodies



- depressional wetlands, coastal lagoons, lakes, streams, rivers and estuaries
- plankton, benthos, dissolved
- across many land use types

Southern CA Screening Assessments for Cyanotoxins

Probabilistic Studies

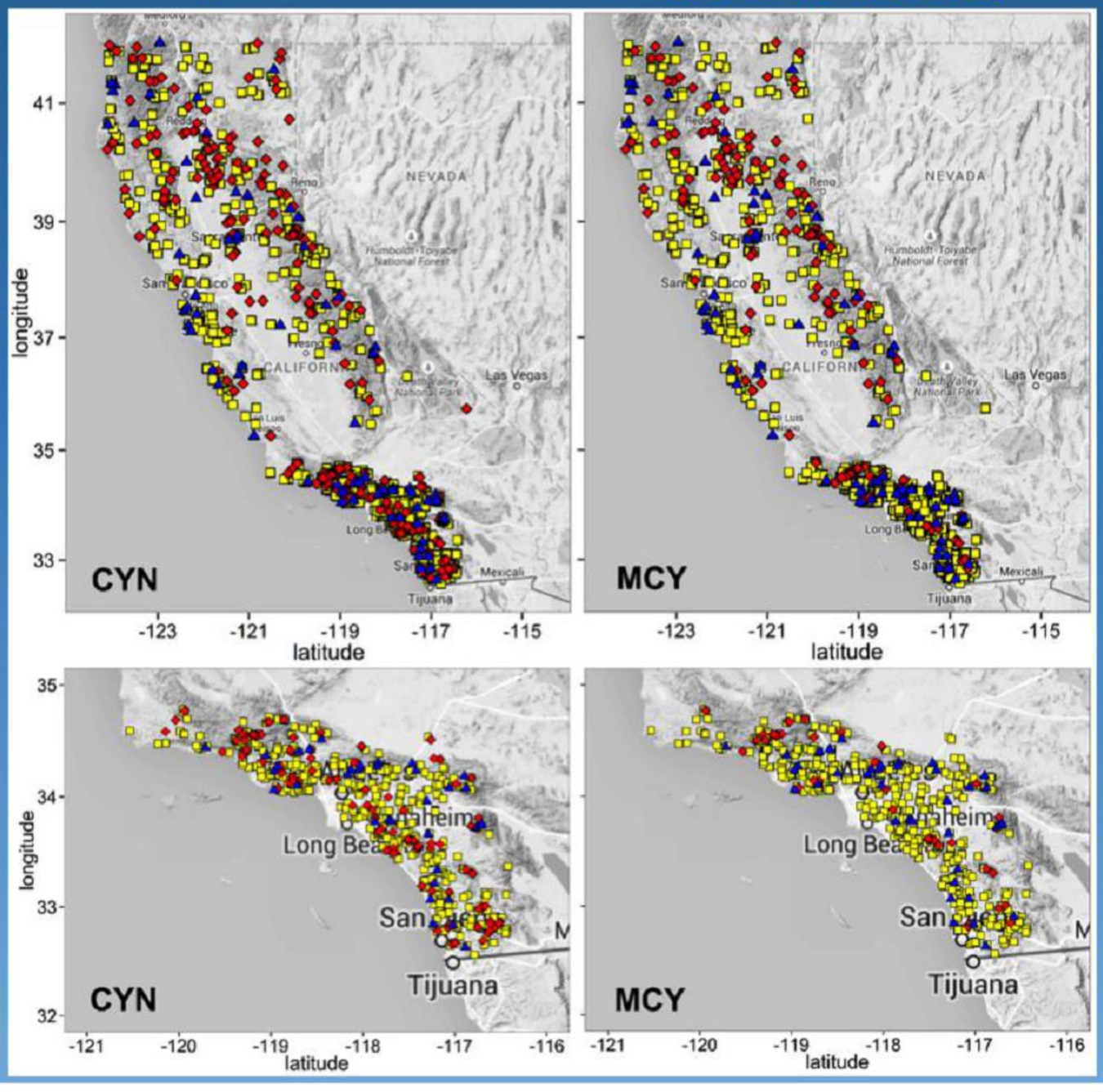
- Wadeable Streams (benthic algae)
- Depressional Wetlands
    - Regional Assessment
    - Important for habitat and groundwater recharge

Targeted Studies

- Lakes, Estuaries and Coastal Lagoons, Reservoirs
    - Mostly recreational and wildlife habitat
    - some drinking water reservoirs

Distribution of cyanobacterial 'toxic' taxa in wadeable streams

Cyanotoxins **Microcystins only**



Potentially toxic taxa at genus level

Potentially toxic taxa at species level

No toxic taxa

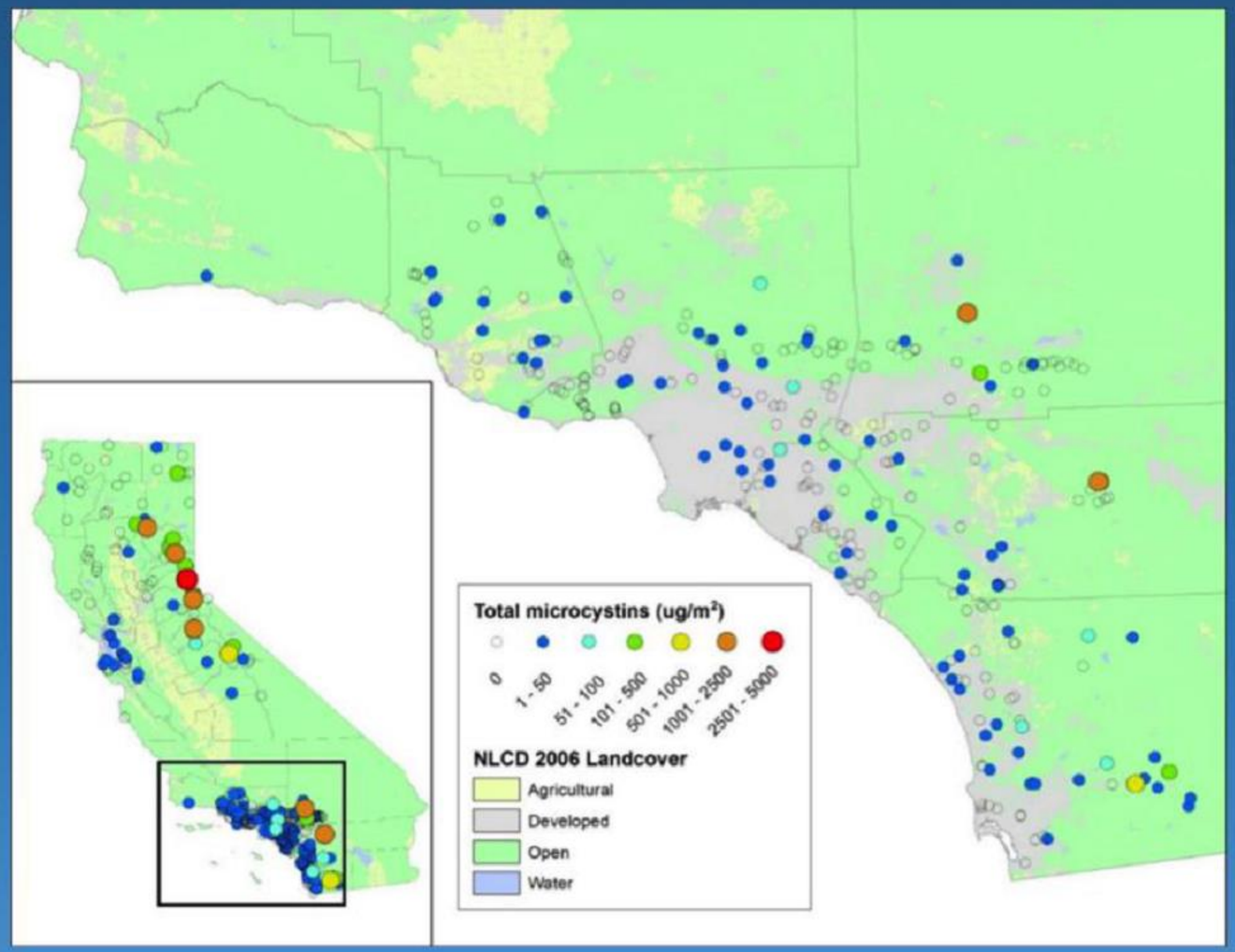
2007 - 2013
1,280 sites

90% of stream kilometers support toxic genera

23% of stream kilometers support toxic species

Fetcher et al. submitted

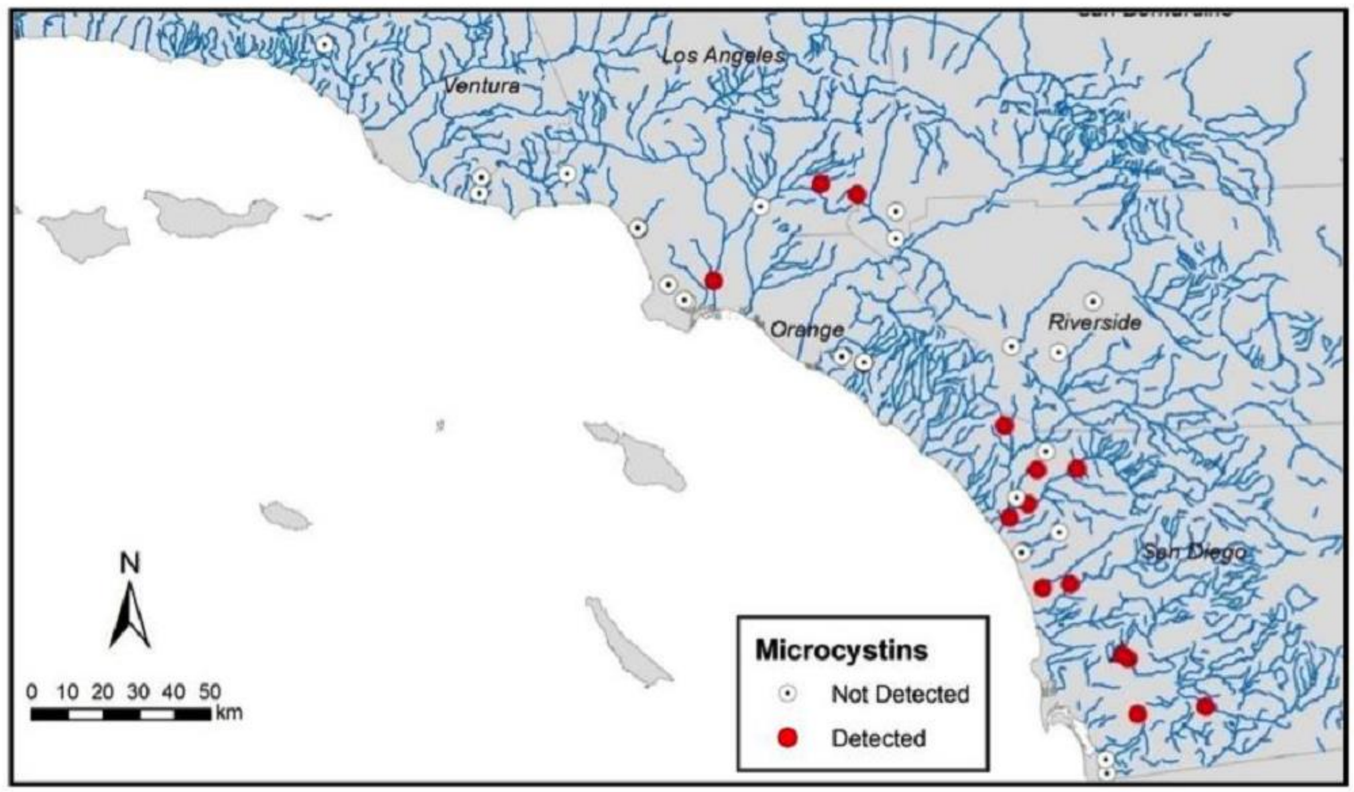
Microcystins Detected in *Benthic Algae* in Wadeable Streams

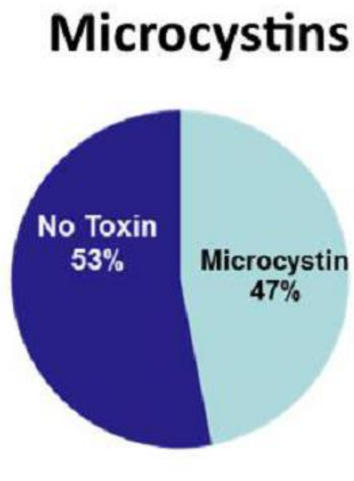


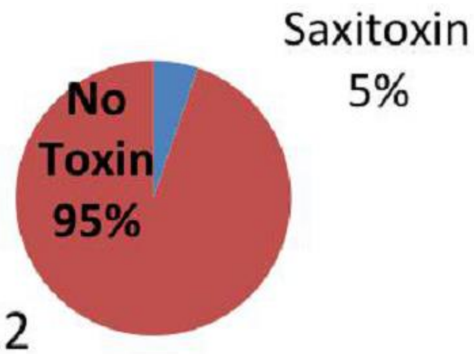
- First study to detect cyanotoxins in benthic algae from streams in CA
- Additional toxins detected at a subset of sites: lyngbyatoxin, anatoxin-a, saxitoxin
- Streams potentially a source of toxin loading to waterbodies downstream

Fetcher et al. submitted

Microcystins Detected in ~50% of Depressional Wetland Sites







Probabilistic study that collected one time grab samples in Spring 2012
2 sites exceeded CA action levels

Newly Developed Monitoring Tool: SPATT

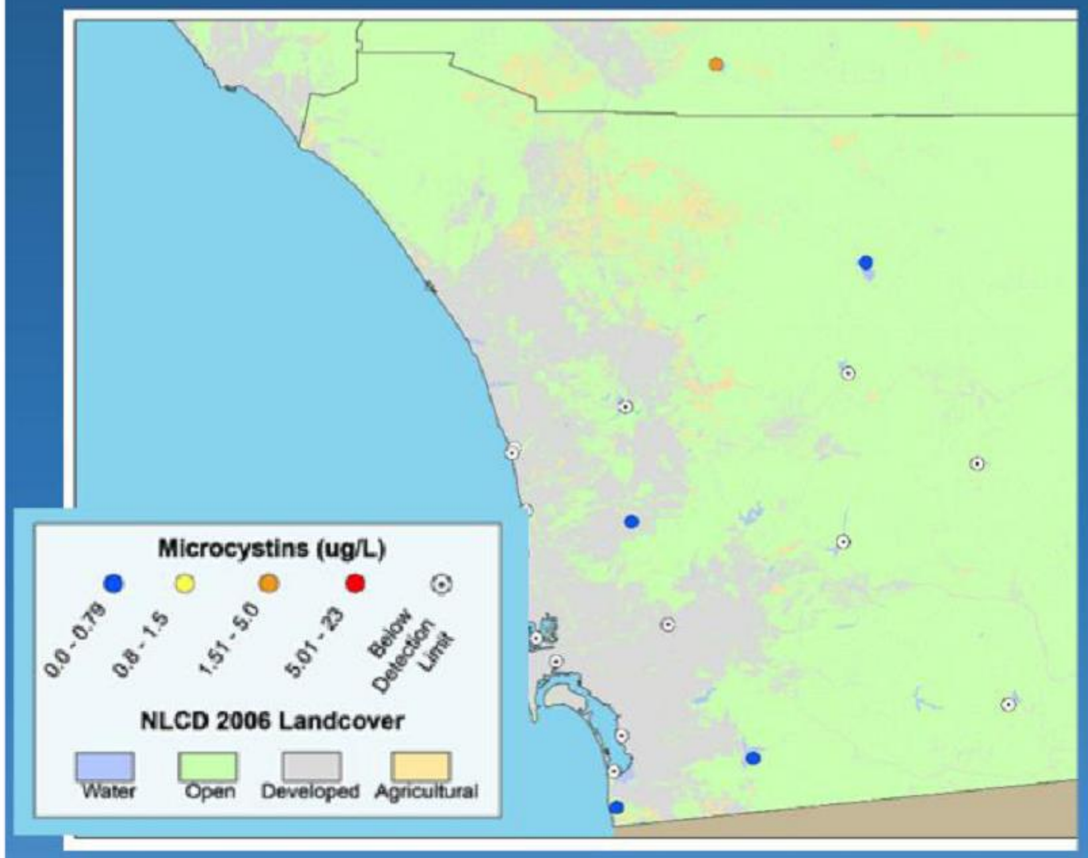
Solid Phase Adsorption Toxin Tracking (SPATT)

- Passive Sampler that is time-integrative
- Provides continuous toxin detection to capture ephemeral events
- Applicable in all waterbody types and for many different toxins
- Cannot distinguish between a pulse of high toxin concentration or consistently low toxin concentrations

Lane et al 2010; Kudela et al 2011

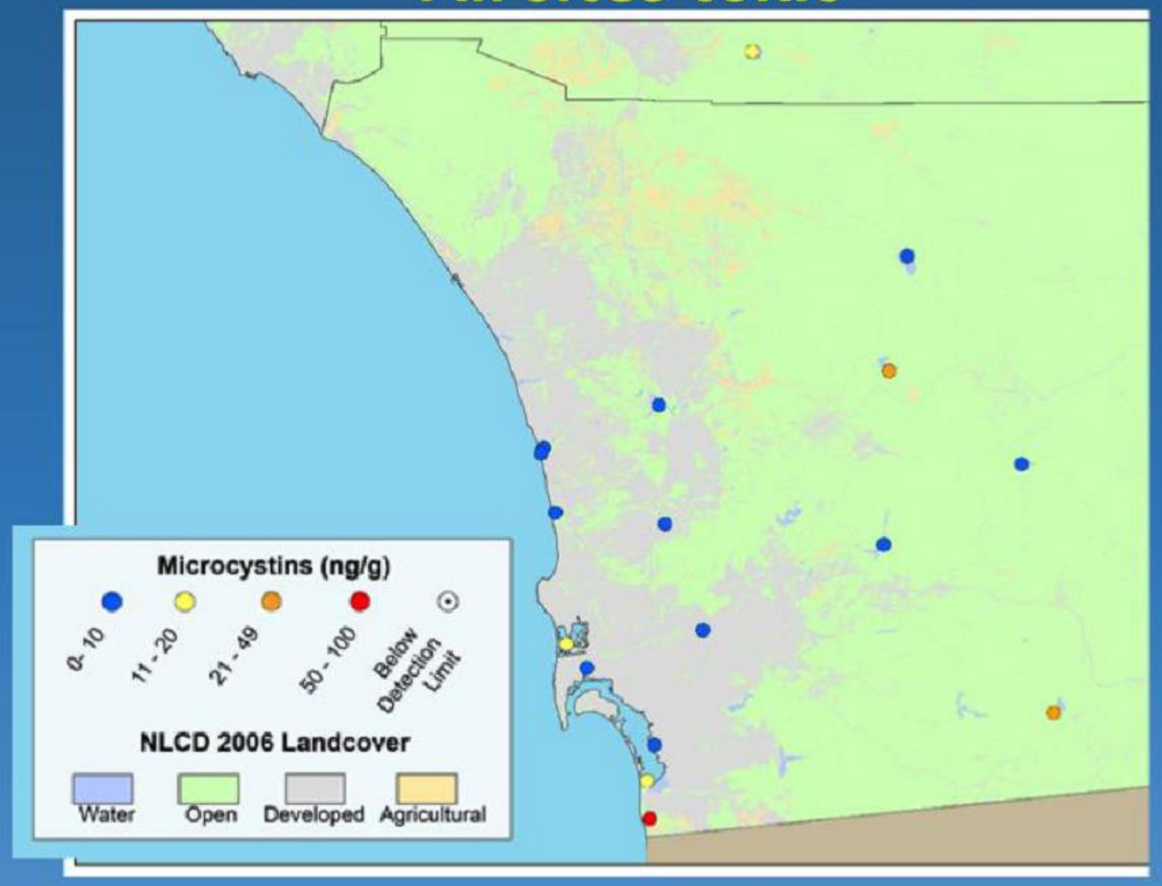
Grab Samples Can Miss Toxins!

Grab Sample Results



SPATT Sample Results:

All sites toxic



Similar results in depressional wetlands:

	% of sites toxic:
Grab Samples	29%
SPATT Samples	83%

What is CA Doing about Freshwater HABs?

- California Cyanobacteria Harmful Algal Bloom network (CCHABs)
  - Workgroup of the California Water Quality Monitoring Council
- Health Advisory Thresholds
- Statewide Freshwater HABs Strategy
  - Long-term vision and strategy to mitigate effects of Freshwater HABs in CA
- Surface Water Ambient Monitoring Program (SWAMP) Freshwater HABs Program

California Cyanobacteria HAB Network (CCHABs)

- Composed of federal agencies, state agencies, tribal governments, local agencies, academics and researchers, and other stakeholders
- Goals include:
  - Coordinate monitoring and management of cyanoHABs
  - Develop collaborative relationships amongst stakeholders
  - Make efficient use of federal, tribal, state, regional, and academic resources to address cyanoHAB issues

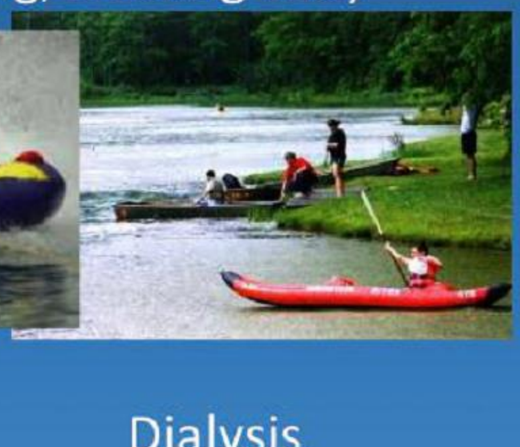
Email list serve: cchabs@sccwrp.org
Email Meredith to be added: mhoward@sccwrp.org

http://www.mywaterquality.ca.gov/monitoring_council/cyanohab_network/index.shtml

Exposure Pathways and Health Advisory Thresholds

Ingestion of contaminated fish and shellfish

Inhalation of aerosols and water (from recreational activities such as swimming, jet skiing, boating etc.)

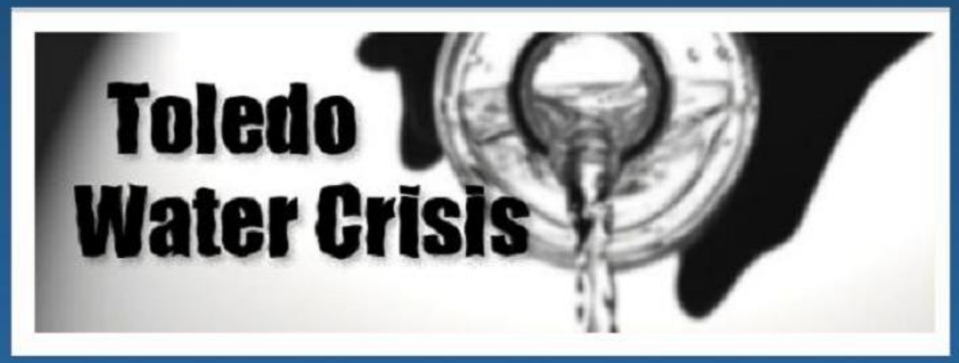


Drinking Water

Dialysis
Blood transfusions

	CA Recreational Action Thresholds	*EPA Drinking Water Thresholds*
Microcystins:	0.8 ppb	0.3 ppb
Cylindrospermopsin:	4 ppb	0.7 ppb
Anatoxin:	90 ppb	

http://www.oehha.ca.gov/risk/pdf/cyanotoxins053112.pdf
http://yosemite.epa.gov/opa/admpress.nsf/0/547dc50c15c82aaf85257e3d004d7f67?OpenDocument



CBSNEWS Video US World Politics Entertainment Health MoneyWa

CBS/AP / *August 3, 2014, 5:06 PM*

Toledo water crisis in second day, but problems long coming

Water crisis grips hundreds of thousands in Toledo area, state of emergency declared

BY TOM HENRY
BLADE STAFF WRITER

CA Freshwater HAB Strategy and SWAMP Freshwater HABs Program

- Statewide Freshwater HABs Strategy
  - Long-term vision and strategy to mitigate effects of Freshwater HABs
  - Build infrastructure to support HAB mitigation, event response and implement statewide monitoring program
    - Centralized website and reporting system (data management, reporting, bloom tracking)
    - Guidance documents (how to collect and analyze samples consistently throughout the state; what to do during a HAB event)
    - Training Programs, including education and outreach

- SWAMP Freshwater HABs program
  - Resources to support infrastructure outlined in the strategy (completed in 2016 & 2017)
  - Multiple trainings, webinars in 2015 & 2016
  - Remote sensing to detect blooms and identify cyanoHABs – collaboration with NOAA
  - Initiate a statewide freshwater HABs monitoring and assessment program

Thank You

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